IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

**In re application of:**

Larry C. Olsen et al.

**Application No.** 10/581,281

**Filed:** May 31, 2006

**Confirmation No.** 3124

**FILED VIA EFS**

**For:** THERMOELECTRIC DEVICES AND APPLICATIONS FOR THE SAME

**Examiner:** Shannon M. Gardner

**Art Unit:** 1795

**Attorney Reference No.** 23-65037-09

FILED VIA ELECTRONIC FILING SYSTEM
COMMISSIONER FOR PATENTS

**DECLARATION OF JOHN DESTEESE UNDER 37 CFR § 1.132**

JOHN G. DESTEESE, being duly sworn does hereby declare and affirm the following:

That he received a Bachelor of Science degree in Electrical Engineering from the University of London in 1960; that he has over 48 years' experience in analysis and development of power delivery systems that extract, convert, transport or store energy.

That he is a co-inventor of the invention claimed in Application No. 10/581,281 and that he is employed by Battelle Memorial Institute, the Assignee of Application No. 10/581,281.

That he was employed as a Senior Development Engineer in the aerospace industry at both TRW, Incorporated from 1964 to 1966 and McDonnell Douglas Corporation from 1966 to 1973; that he previously worked as a Research Engineer in the electric power industry at Westinghouse Electric Corporation, from 1961 to 1964; that he contributed to the development of thermoelectric generators and other direct energy conversion devices for each of these prior employers.

That he currently is a Staff Engineer and has been employed by Battelle Memorial Institute since 1973; that his professional experience covers a broad range and includes advanced energy conversion research and development; innovation and analysis of system concepts, and planning, integration and management of system development programs; that his research specialties currently include the capture of heat and other forms of ambient energy and their conversion into electrical power and that he continues to lead Battelle Memorial Institute research to further improve the developed thermoelectric power sources and methods.

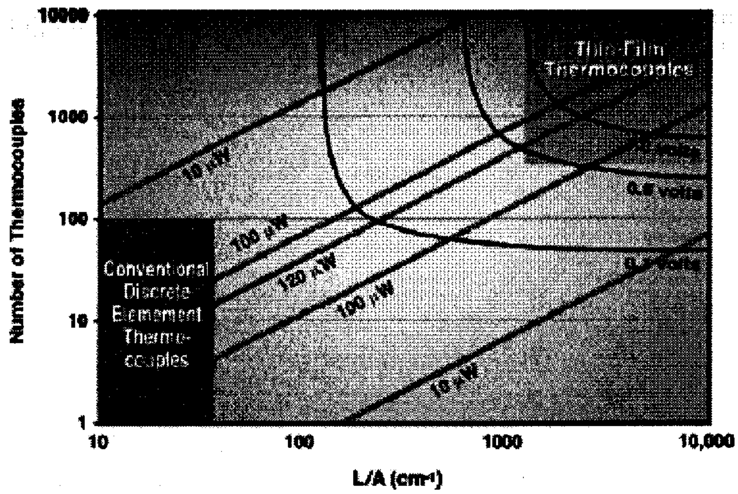
That he has read the Examiner's rejections in regard to the pending claims in Application No. 10/581,281 in the Office action dated December 16, 2009, the Migowski and Böttner references cited therein.

That he actively participated in the conception, research and development of the thermoelectric power sources and methods as disclosed in this and related applications. That he actively participated in studies and testing leading to the unexpected discovery that the L/A ratio is a variable with significant (critical) effect on the resulting power of the device and methods using such devices. That specifically, this unexpected discovery revealed that the power and voltage of devices can be expressed uniquely as contours on a graph having the number of elements as its ordinate (y-axis) and L/A of the constituent thermoelements as the abscissa (x-axis) and depending upon the L/A ratio used, it provided design guidance for achieving previously unexpectedly high voltage and power output. That with such testing and discovery, the Applicants identified preferred and critical design regimes based on thermoelement L/A ratios as illustrated in the figure below, where output voltage contours and iso-power lines are shown on a chart of thermocouple number versus L/A ratios.

That, for a given difference in source and sink temperature, he achieved unexpected results when varying the L/A ratios to define preferred design configurations. That through testing and analysis he discovered the following: that L/A ratios are variables critical to achieving the desired power performance of thin-film, multi-element thermoelectric generators; that particular L/A ratios are critical to achieve the Applicants' device desired output power; that the width of the deposited thermoelectric film and the film thickness determine the area of each thermoelement and are, in turn, important design parameters that control the internal resistance, output voltage and power of an multi-element assembly; that the voltage of a thermoelectric (TE) generator is governed by the number of thermocouples, differences in temperature that can be employed and the *Seebeck* coefficient (i.e. the voltage output per unit of temperature capability) of all of the thermoelements in an assembly; that the electrical and thermal conductivity of thermoelements and thermoelement shape determine the internal electrical and thermal resistance of the generator. That the L/A ratio is a critical variable for achieving a desired electrical resistance of an assembly so that a useful electrical output current results when voltage is generated in the TE assembly, and that the L/A ratio controls the amount of heat that is transmitted through the TE assembly from the hot to the cold side.

That each plot as shown in the figure below as based on temperature difference, available thermal energy and intrinsic material properties will define a preferred and critical design region in which the L/A ratio of thin-film thermoelements is much higher than can be achieved with discrete, self-supporting thermoelements. That for given conditions, L/A ratios higher than the upper limit of the presently claimed range (10,000 $cm^{-1}$) produce lower power devices because implicitly higher internal

resistance of the TE generator limits output. For example, the 11-microwatt thermogenerator for a watch disclosed by Migowski has thermoelements with an L/A ratio of 15,000 $cm^{-1}$ which is off scale beyond the upper range of the figure and claimed L/A ratios. That an L/A ratio as high as Migowski discloses limits output power to between 10 and 20 microwatts in the configuration of his device and the watch interior in which it is designed to operate.




That the L/A ratio is a critical aspect in the design of the disclosed and claimed thermoelectric power source that includes multiple p-type and n-type thermoelements. That through his research and analysis he discovered that an L/A ratio greater than 20 $cm^{-1}$ (100 $cm^{-1}$ for example) is critical for Applicants' preferred low-power applications – to which power applications the disclosed thermoelectric devices and methods are aimed. That once the Applicants discovered that varying the L/A ratios produced unexpectedly high power output devices, they carefully evaluated different L/A ratios to achieve a device and methods using such devices having useful voltage directly without need for further amplification and an electrical impedance match with the electrical circuit of the application (e.g., a sensor and/or transmitter) in a relatively small power source device. That the unexpectedly superior results in the developed thermoelectric devices and methods as claimed produce a thermoelectric generator that can be treated similar to a "plug-in" battery with a comparable voltage, thereby eliminating the need for voltage amplification components and their inherent power consumption.

That the following table illustrates a direct comparison of the presently claimed methods for producing power with that disclosed by Migowski. That for the purposes of achieving as direct of a comparison between the presently claimed invention and the Migowski device (to the extent it is disclosed), the following design variables are the same for several disclosed designs of the presently claimed invention as those disclosed in Migowski (such that only the L/A ratio is varied):

- Number of thermocouples is 7500;
- Temperature difference is 6°C;
- Thermoelement length is 0.075 cm.

And that Applicants' examples are further based on Applicants' thermoelements' composition *Seebeck* coefficient of 260 μV/°C, being bismuth telluride and antimony telluride co-sputtered on polyimide tape. Migowski does not disclose the composition of its thermoelements or a *Seebeck* coefficient for its thermoelements nor sufficient information to determine such aspects of its device.

That values of electrical conductivity used in the calculations are 0.002 Ω-cm and 0.01 Ω-cm for p-type and n-type thermoelements, respectively. That the criticality of the L/A ratio in the Applicants' examples is demonstrated by varying the thermoelement width and/or thickness (hence, the L/A ratio) while holding all other parameters constant. The computational method utilized to produce the comparison data for Applicants' disclosed devices and methods utilized a custom-designed EXCEL® spreadsheet tool with the steps including:

1. Estimating the maximum open circuit voltage (E) provided by the number of thermoelements, the *Seebeck* coefficient of the thermocouples and the temperature difference to which they will be exposed;
2. Next the resistance of thermoelements is calculated according to the formula $R = \rho L/A$ where R is resistance in ohms, ρ is resistivity in Ω-cm and L and A is the length and area in cm and $cm^2$, respectively;
3. The total internal resistance ($R_t$) is summed from the above for all thermoelements in the assembly;
4. Maximum power of the assembly ($P_{max}$) is calculated from the formula $P_{max} = E^2/4\ R_t$ where E and $R_t$ are as defined above.

In this manner the power of any thermoelectric assembly can be calculated and displayed against the L/A ratio. The power of the Migowski device was disclosed in Migowski as 11 μW as shown below.

| Device Parameters | Embodiment of Applicants' Disclosed Device Example 1 | Embodiment of Applicants' Disclosed Device Example 2 | Embodiment of Applicants' Disclosed Device Example 3 | Migowski Disclosure |
|---|---|---|---|---|
| Number of Thermocouples | 7500 | 7500 | 7500 | 7500 |
| Temperature Difference (°C) | 6 | 6 | 6 | 6 |
| Thermoelement Length (cm) | 0.075 | 0.075 | 0.075 | 0.075 |
| Thermoelement width (cm) | 0.5 | 0.05 | 0.01 | 0.01 |
| Thermoelement Thickness (cm) | 0.0003 | 0.00075 | 0.00075 | 0.0005 |
| Thermoelement L/A ($cm^{-1}$) | 500 | 2000 | 10,000 | 15,000 |
| **Output voltage (V)** | **5.85** | **5.85** | **5.85** | **1.6** |
| **Power (μW)** | **759** | **190** | **38** | **11** |

That the table above illustrates that varying L/A ratios in consideration of material properties and other design requirements produces Applicants' disclosed device with up to 70 times the output of the

Migowski disclosed device when constrained by similar design limits[1] and exposed to the same environmental conditions. That the examples provided in the table essentially cover the claimed L/A ratio range of from 100 $cm^{-1}$ to 10,000 $cm^{-1}$ and that the devices and methods of the present invention provide significantly higher voltage and power output than achieved by the Migowski device.

That Applicants' disclosed and claimed power source methods can operate at a temperature difference up to about 20°C and that in such condition and without other design changes, each of the Applicants' examples would produce at least another 3 times more power than that shown in the above table. Further, because of the constraints of making a direct comparison with Migowski's disclosure, none of Applicants' examples presented above is even optimized for operation in environments where temperature differences larger than 6°C are experienced (since the Migowski reference discloses information only for a 6°C temperature difference). In consequence, the above table does not illustrate the further importance that Applicants' claimed power source methods, as governed by the L/A ratio of the thermoelements, can produce electric power in the range from milliwatts to about a watt simply by harvesting naturally abundant thermal energy. This six-order of magnitude range of power potential from naturally occurring thermal energy sources is remarkable and by its very nature of being so significantly improved over any prior art, was clearly unexpected by those who have contributed to the prior related art.

That Applicant's claimed power source designs were driven by Applicants' recognition that thermoelectric devices could be innovatively designed to capture naturally occurring thermal energy in an unbounded environment to produce useful ranges of electrical power. And that Applicants' claimed power source methods incorporate this important design feature never considered or taught by those who contributed to the prior art. That Applicants' power sources hence are able to operate in environments the prior art has not even recognized, explored or suggested as being viable for production of such electrical power ranges from such environmental sources.

That besides the fact that Migowski did not recognize the importance of the L/A ratios, Migowski would not have been in any manner motivated to change the L/A ratio of his thermoelements because of Migowski's focused endeavor of producing a watch battery backup power source or other low-level power needs devices. That is, Migowski designed his device with the power he needed for a watch and like applications.

The undersigned declares that all statements made herein of his knowledge are true and that all statements made on information and belief are believed to be true and further, that these statements were made with the knowledge that willful false statements and the like are punishable by fine or

[1] Again, note that because Migowski does not teach what compositions are used for its thermoelements or disclose a *Seebeck* coefficient for the materials, there cannot be an absolute direct comparison – that is, nothing in Migowski teaches or suggests it

imprisonment under Section 1001 of Title 18 of the United States Code, and that any such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Executed at the place and date opposite the signature below.

_______________________________
John G. DeSteese

At _______________________________
(City and State)

on this _______ day of __________________, 2010

uses the compositions of the presently claimed invention.